QUANTITATIVE ANALYSIS OF THUMB RANGE OF MOTION DURING FUNCTIONAL ACTIVITIES

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Abstract. *The human hand is an anatomic structure able to do many functional activities. However, the most important of these functions is the prehension. The ability to grasp things is based in thumb stability and mobility that provides the force and direction control during the pinch movements. The use of realistic mathematical models can be of great utility to determine movement patterns and evaluation procedures. The evaluation determines the impairment presence and surgery and rehabilitation needs. The correct determination of these procedures makes possible to compare different surgery techniques and the better therapy choices, basing quantitatively the decision process during the treatment. This work aims to measure the trapeziometacarpal range of motion during the two pinches and one prehension in health individuals and to design the trapeziometacarpal joint (TMCJ) analysis methodology, verifying its reability. The kinematics data will be obtained by stereophotogrammetry (Qualisys-Pro reflex motion analysis system).*

Keywords: *Biomechanics, trapeziometacarpal joint, 3D models, stereophotogrametry, prehension*

1. INTRODUCTION:

The hand is an excellent model to study of the biological motion systems. Your neural and biomechanical architecture lead to valuable questions for strategy control understanding, which are connected in the motion coordination of fingers and the forces that are necessary to execute a large variety of tasks. Those tasks are since the multi-digital prehension until reach the finger's moves individually. The ability to do individual moves comes relatively later, in both animal evolution and individual development. The multi-digital prehension (the hand's most diary use) provides the necessary moves needed for tasks like write, paint, sculpture, play musical instruments and so for (Schieber & Santello, 2004). A large quantity of experimental visions in which includes kinematics studies of hand and fingers motion, eletromiography and cortical activities data, all of them have been leading the hand's motion functions understanding and allowing the development of some replacement techniques in cases of lesions.

Those lesions currency in hands can frequently (depending the lesion's level) lead to heavy functional loss. It does interfere in life's quality, in productivity and the human being social relations. The most global knowledge can be used to explain diagnostics and create more effective rehabilitation programs, hence, minimizing the treatment costs and lost by the person. In Brazil, Social insurance's research data shows that 34.2 % of the accidents while people work are related to hands and fist. Without the capacity to execute the basic movements of the hand, as the opposition and the counter-opposition of the thumb to one of the other fingers, the individual is disabled to execute tasks of simplest (multi-digital hold) to the most complex (to write, to paint, to play instruments) of efficient form and without the aid of some other mechanism. These abilities loss can drastically affect the social relations and quality of life of the human beings. The measurement of the articulate movements of the hand human being, using technology in 3D, has been a resource necessary to answer to the reality of its movements. "Table 1" below shows some details of these researchers:

Table 1 – Research evolutions in hand study

Author	Joint	Biological nature of the Study	Methodology
Chao *et al.,* 1976	Hand	*In vivo*	bi-planar Radiography
Cooney *et al*., 1977	Thumb	*Ex vivo*	Radiography, 2D
Cooney *et al*., 1981	TMCJ	*Ex vivo e In vivo*	3D
Gordon *et al*., 1991	TMCJ	virtual model	3D
Hollister *et al*., 1992	TMCJ	virtual model	3D
Giuritano *et al.,* 1994	TMCJ	Virtual mathematical model	3D
Rondinelli *et al*.,1997	Hand	*In vivo*	Splint TMCJ blocker
Bermarck & Wiktorin 2002	Hand	*In vivo*	Accelerommetry /stereophotogrammetry
Araújo *et al*., 2002	Hand	*In vivo*	Muscular force
Figueroa *et al*., 2002	Hand	*In vivo*	3D, stereophotogrammetry
Kuo *et al*., 2002	Thumb	*In vivo* (superficial marks)	3D, fluoroscopy
Kuo *et al*., 2003	TMCJ	*In vivo*	3D, eletromiography
Vergara *et al*., 2003	Hand	*In vivo*	3D, digital photography
Kuo *et al*., 2004	TMCJ	*Ex vivo*	3D, stereophotogrammetry
Yokogawa & Hara 2004	Thumb and index finger	*In vivo*	3D, stereophotogrammetry
Capoozzo *et al*., 2004	ADM	*In vivo*	3D, stereophotogrammetry
Chiari *et al*., 2004	ADM	*In vivo*	3D, stereophotogrammetry
Leardini *et al.,* 2004	ADM	*In vivo*	3D, stereophotogrammetry
Miyata *et al*., 2004	TMCJ	*In vivo*	3D, stereophotogrammetry
Weiss *et al*., 2004	TMCJ	*In vivo*	3D, stereophotogrammetry
Croce *et al*., 2005	ADM	*In vivo*	3D, stereophotogrammetry
Golbier *et al*., 2006	TMCJ	*In vivo*	3D, optoelectronic

2. METHODOLOGY

2.1. Data processing

The captured data initially had been processed by software of acquisition Qualisys Track Manager® 1.6.0.x (QTM). This software did some interpolations when the trajectory of the MPR's has been lost for in the maximum 10 frames. The causes of the loss of trajectory can at least resume in blockage or impossibility of the mark to be seen by two cameras. In this in case that, the interpolation process uses an algorithm that reconstructs the possible trajectory of this lost MPR's. After that, the data are exported to the software developed in the Bioengineering Laboratory of UFMG (LABBIO) in Matlab environment. The main function of this software is to create a system of coordinate for each segment from the positions of the anatomical marks captured by the QTM in the reference position and hence determine the positions and instantaneous orientations of each segment. Thus, system QTM was responsible for capturing the trajectory of the markers and the software of the LABBIO for processing the data to create the segments and to calculate the angular displacements. The data had been filtered and normalized, to generate curves of the kinematics properties (angular variation of the TMCJ in the plans frontal, sagital and transversal).

Through the MPR's the anatomical model of the composed biomechanical for the one before arm, trapeze and first metacarpal was constructed. The MPR's located in "epicondyle" of the radio (MPR1), in the processes ulnar styloid process (MPR2) and radius (MPR3) had been used to define the plan of forearm corresponding to the anatomical plan frontal. The MPR located in the process radial styloid process and average point 1 (PM1) had defined the segment radio-trapeze. The lateral MPR's located (MPR4) and medially (MPR5) to the located TMCJ and the lateral MPR's (MPR6) and medially (MPR7) to the MCF had defined the metacarpal first segment (through average points PM1 and PM2 – "Fig. 1").

In this model the segments are considered as rigid bodies (Mitchel, 1995; Cappozzo *et al*., 2005). The system of coordinated (B1) associate to the rigid body has its first axle defined through the segment radio-trapeze, axle X, that it has the same direction that vector MPR3-PM1. As the axle, axle Z, are the 90 degrees of the first one and possess the same direction of vector MPR5 and MPR4. The third axle is product of the two first ones, axle Y.

The determination of the angular variations of the TMCJ involved the localization of an orthogonal base, B1, located in the PM1. For the determination of the angular variation of the TMCJ the vector, called is generated. The angle between this vector and plan ZX are considered the variation of the movement of adduction/abduction of the joint. The angle enters and plan XY is considered the variation of the flexion movement/extension, "Fig. 1". The functional position of reference was considered the position zero or neutral one.

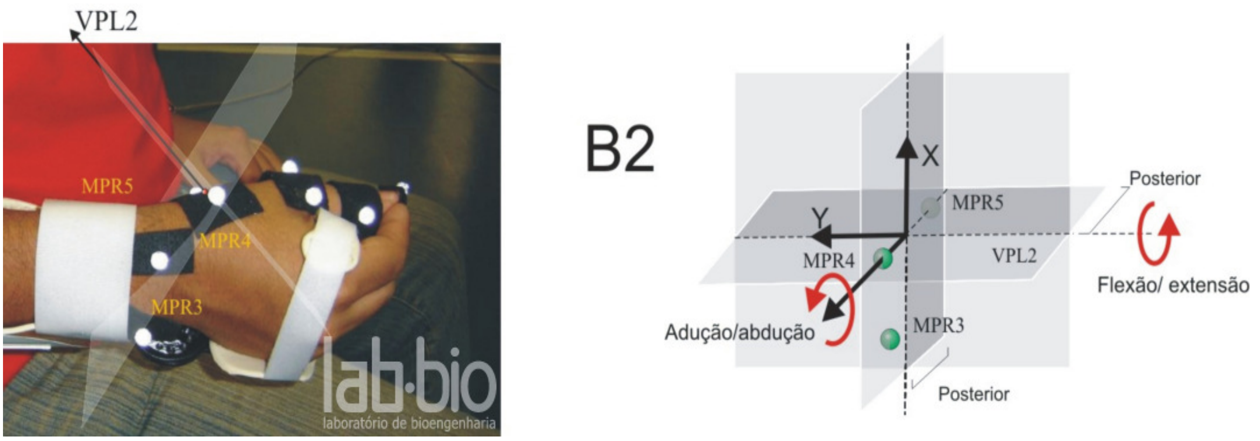

Figure 1. Diagram of the rotation of joint TMCJ is determined by the angle formed for the plan MPR5, MPR4 and PM2, and vector MPR6-MPR7.

2.2. Clinical protocol

After the calibration step, it was possible to collect the angular performance in health individuals doing the adduction/abduction, flexion/extension and rotation. A clinical protocol was developed and had the authorization to be conducted with human beings (COEP-UFMG n. 308/06). The thirty individuals were asked to be seated during the tests with their forearm fixed by a specific and adjustable structure that was developed to maintain the elbow joint in 90^{o} of flexion, the wrist joint in 20 of extension to provide the functional position, "Fig. 2".

Figure 2. Photo of the individuals positioning and structure able to provide the functional position.

3. RESULTS AND DISCUSSION

This study has as objective to determine in 3D the position, orientation and functional angular variation correspondents to the movements of the TMCJ during the execution of the lateral, tripude and cylindrical pinches, in healthy individuals, between 20 and 40 years of age (average of 27,6), of both male and female kind, from the stereophotogrammetry technique. The angles to articulate had been evaluated during the movements of pinches in 3D in alive, using the system of analysis of movement Qualysis - ProReflex MCU, from the MPRs positions data.

The first advantage of this method was to have made possible necessary the direct register and of the angles to articulate. Another advantage was to have made possible the determination of the angular variation and the contribution of the movements evaluated during the performance of the lateral, tripude and cylindrical pinches. It was evident that the angular variation of the abduction/ adduction was predominant in these activities and greater (approximately 10 degrees) for the lateral and tripude pinches in comparison with the angular variation of the abduction/ adduction in the execution of the cylindrical pinch (approximately 8 degrees). Among the angular variation, the flexion/extension was lesser for the 3 movements (approximately 6 degrees). The rotation, even so lesser of what the abduction/ adduction abduction/ adduction was the second registered greater.

Analyzing the results of global form, it is possible that these have reflected common aspects of some described factors already in literature as individual and real time variations of standards of hold (Rondinelli *et al*., 1997; Araújo *et al*., 2002; Schieber *et al*., 2004). Also, it is possible to conclude that the used methodology was efficient in detecting the angular variations of the lateral, tripude and cylindrical pinches in the studied population. It is important to detach that the method was capable to carry through the capture of the data of dynamic form, simultaneous and in real time during the movements. Moreover, it is possible to suggest that the functional angle in the performance of these pinches requires minimum amplitude.

The planning based on results gotten in this study presents the potentiality to take care of the frequent requests of carriers of non capable alterations of the TMCJ to the return of the activities of daily life. As well as, to take care of the demand of the surgical or clinical treatments of the hand that aim pain modulation, improving of aesthetic and the re-establishment of the function, becoming possible to quantify the results of therapeutical interventions (immobilizations through splints) and of surgical procedures for evolution

4. CONCLUSION

This study has characterized by means of the technique of sterophotogrammetry the angular variation of the TMCJ during the execution of the lateral, tripude and cylindrical pinches in the adduction/abduction axles, flexion /extension movement and rotation of non-invasive, dynamic and simultaneous form, allowing that these activities were executed spontaneously in individual data.

The anatomical characteristics of the TMCJ (small dimensions of the bones, three degrees of freedom and positioning of the bone trapezium), all of them are restrains in the sterophotogrammetry. They had been contouring for the substitution of "cluster" for MPRs, the positioning of the MPRs in permanent anatomical references (folds of flexion) and for the methodical procedure of identification of the bone trapezium.

In the angular variation, the adduction/abduction movement was predominant in the studied pinches (approximately 10°) and the rotation movement (approximately 7°) less is found last requested (approximately 4°) had equal participation in the performance of the activities.

The reliability of the experiments was shown by the accuracy of the measures of the 3 segments (radio, radio-trapezium and metacarpal) where the MPRs had been fixed in two different collections and by the coincidence of the peaks during the registers of the executed activities.

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6. RESPONSIBILITY NOTICE

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